Electronics Devices & Materials

Annual Technical Report SFA007A

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Annual Technical Report SFA007A

Electronics Devices & Materials

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14. ABSTRACT

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ABSTRACT

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1.0 INTRODUCTION

SFA, Inc. was tasked to conduct a broad range of research linked to electronic devices, materials, circuits and assemblies at the Naval Research Laboratory Electronics Science and Technology Division (ESTD). The work was both theoretical and experimental and often involves the development of analytical, fabrication, diagnostic and characterization techniques. The objective of this electronics research was to provide new state-of-the-art electronic devices and circuits for experimental systems used to solve problems of military significance. Areas of electronics emphasis include solid state electronics, biochemical sensors, semiconductor materials, surface and interface science, microstructures, nanostructures, opto-electronics, microwave components and studies of magnetic phenomena. Special emphasis is placed on silicon, III-V compound semiconductors, reliability physics of electron devices, the hardening and vulnerability assessment of electron devices, components and assemblies, the development of high-performance microwave and millimeter wave tubes and components, and the development of submicron fabrication techniques.

2.0 SCOPE

2.1 STATEMENT OF WORK TASK 3: NANOELECTRONICS FACILITY SUPPORT

The Electronics Science and Technology Division operates modern nanometer and micrometer fabrication facility identified as the Compound Semiconductor Processing Facility (CSPF). This facility specializes in making structures and devices that require the equipment (e.g. advanced patterning using electron beam lithography), spaces (class 1000 clean benches), and skills (appropriate mix of skilled technicians and professionals) associated with microelectronics and nanoelectronics technologies. Although the end user of the fabricated prototype structure or device is likely to be part of an experiment to benefit electronics technologies of importance to the Navy; the facility also creates structures and devices with other scientific or technological goals being pursued at NRL or to other similar research institutions.

2.1.1 Sub-Task 2: Assemble Integrated Circuit Devices

The contractor shall supply personnel capable of assembling micro and nanoelectronics devices using the following equipment; wafer saw, ball and wedge bonders and epoxy die attachers.

2.1.2 Sub-Task 4: High Resolution Photolithographic Services

The contractor shall provide UV and Deep-UV lithographic expertise to CSPF. Exposures can be aligned to existing substrate features or the exposure can be unaligned. Minimum feature size of 1 micrometer will be expected routinely on a 3" wafer.

2.2 STATEMENT OF WORK TASK 4: RADIATION EFFECTS EXPERIMENTAL WORK

The ESTD Solid State Devices Branch performs basic and applied research in the effects of radiation on microelectronic devices, materials, and systems. The sources of radiation include the natural radiation environment of space and, at high altitude, radiation sources such as accelerators, and radiation from nuclear events. The microelectronic devices include advanced digital and analog technologies such as quantum devices and commercial microprocessors. The materials include LT-GaAs, SOL, and advanced solar cells. The systems include subsystems for space systems. Effects include single event effects, total dose changes (especially including space low-dose-rate effects), displacement damage effects, weapon dose-rate effects and other system effects.

2.2.1 Sub-Task 1: EXPERIMENTS AND TESTING

The Contractor shall carry out the following radiation effects experimental work at NRL and other radiation facilities as required:
Perform particle and gamma irradiations at various facilities on various kinds of advanced devices such as solar cells, integrated circuits detectors, metal oxide semiconductor field effect transistors (MOSFETS's), charge coupled devices (CCD'S), and Resonant Tunneling Devices (RTD) quantum devices. Schedule time and oversee dosimetry in a coordinated radiation and device environment. Characterize devices before and after irradiation, including post irradiation effects and annealing. Characterize properties of semiconductor materials and devices such as carrier concentration, minority carrier lifetime, trapping levels and cross sections, conversation efficiency and mobility using a range of experimental techniques such as Hall effect, electrochemical capacitance profiling, deep level transient spectroscopy, quantum efficiency and reflectance, and current-voltage measurements made both in the dark and illuminated. Characterization to be made over a range of temperatures and other environmental conditions. Support an experimental program testing single event effects induced by ions and pulsed lasers on advanced integrated circuits and technologies.

2.2.2 Sub Task 2: MODELING:

The contractor shall carry out the following radiation effects modeling work as required: Extend various modeling and statistical techniques to energy deposition for both ionizing and non ionizing effects in semiconductor and dielectric materials and devices, with feature sizes covering the macro-, micro, and nano-regimes. Apply difference modeling and statistical approaches to space radiation environmental effects such as solar proton events and trapped radiation belts. Perform calculations using various computer codes available at NRL on the response of test structures and integrated circuits to energetic ion and pulsed laser perturbations on a picosecond time scale. This will include the effects of the radial extent and shape of the initial charge track and timing effects related to the relationship between the time of interaction and the changing bias conditions of a dynamic circuit.

Support research investigation on the basic mechanisms of radiation effects including total

2.3 STATEMENT OF WORK TASK 5: MICROELECTRONIC TECHNOLOGY SUPPORT

The ESTD Power Electronics Branch carries out a variety of activities involving research and development on: 1) Fabrication, design, and testing of both low voltage and high voltage analog circuits and devices 2) Fabrication and characterization of novel heterojunction material substrates and devices by utilization of direct wafer bonding. This task describes requirements for engineering services for several key research projects at NRL in Washington, D.C. For each subtask described below, the contractor shall keep complete records of all work performed, including fabrication procedures, physical and electrical characterization, and data analysis. The contractor shall consult with Navy personnel on the design of electronic test structures and the development of designs that meet the needs of the experimental program at NRL.

2.3.1 Sub Task 1: Microelectronic Devices and Circuit Design, Testing, and Fabrication

This subtask entails development of analog circuits and devices to perform the given system or sub-system function, e.g. communication, electronic warfare, efficient power switching. The work entails the use of commercial computer aided design (CAD) for circuit design and optimization, and for layout of analog CMOS devices and circuits. The circuits shall be evaluated in the laboratory using standard commercial test equipment such as oscilloscopes and spectrum analyzers. The contractor will design experiments for the fabrication of microelectronic devices and will also electrically characterize both low voltage and high voltage microelectronic devices.

2.3.2 Sub Task 2: Wafer Bonding Fabrication and Characterization

The contractor will fabricate new types of electronics material substrates and new types of electronic devices by using direct wafer bonding. The direct bonded wafers will include substrates of silicon, silicon geranium, silicon carbide, gallium arsenide, gallium antimonide and other III-V materials. The contractor shall develop appropriate methods for cleaning and etching the semiconductor surfaces prior to direct wafer bonding. Existing Government owned equipment shall be used for bonding of semiconductor substrates. The contractor shall investigate the mechanical and electronic properties of the bonded interface. The contractor will fabricate both homojunction and heterojunction devices by direct wafer bonding. The fabricated electronic devices include low voltage microelectronic devices, high voltage power devices, and microwave devices.

3.0 ACCOMPLISHMENTS

3.1 TASK AREA 3

3.1.1 Subtask 2 – Assemble Electronic Devices
3.1.2 Subtask 4 – Photolithography of Electronic Devices.

ASSIGNMENTS: *(Photo Technician)*

- Photolithography, wet and dry etching and metallization of various compound semiconductors and nano-electronics materials at the Microwave Technology Branch at Naval Research Laboratory.

CURRENT PROGRESS FOR EACH TASK:

- Perform various semiconductor processes such as photolithography, wet and dry etching, and metallization.

- Perform optical lithography on various samples as well as the characterization and trouble shooting of required resist process.

- Process samples for various projects such as Antimode Base High Electron Mobility Transistors (HEMT) and Double Heterojuction Bipolar Transistors (DHBT) Fabrication and Photo Diode Fabrication.

- Perform wet and dry etching of InGaAs/InAlAs Multiple Quantum Well (MQW) for Quantum Well Nanomachining and Nanoelectromechanical Systems.

- Responsible for maintenance of the metallization area. Perform metal deposition such as CR, AU, and AL using both e-beam and in-source metallization systems.

SIGNIFICANT FINDINGS AND CONCLUSIONS:

- Research is continuing. Some basics work has been published and substantiated. Reproducible processing is of particular interest currently within this field. This work has contributed greatly to research found in recent papers and presentations.

3.2 TASK AREA 4

3.2.1 Subtask 1 – Experiments and Testing
3.2.2 Subtask 2 – Modeling

ASSIGNMENTS: *(Researcher – Radiation Effects Measurement MBE Growth)*

- IR Detector Measurements: MISSE6 ORMatE-1: Infrared Detector Measurements: Write and test a program to calculate radiation damage effects on solar cells based on NRL's algorithm and MISSE6 Materials Testing

CURRENT PROGRESS FOR EACH TASK:

- Detector measurements are ongoing. Currently, we are investigating the effect of various methods of surface passivation on the dark (noise) currents. We have also begun looking at detectors operating at 5 micron wavelengths as the navy seems more interested in this regime.

- The ORMatE-1device (mirrors, mostly) have all been characterized and the hardware has passed its pre-flight thermal, vacuum and vibration tests. We are now analyzing data and writing various reports on the results of the pre-flight tests. It is scheduled to fly in 2008.

- Detector measurements are ongoing as new detectors are grown.

- A program has been written in Matlab code reproducing NRL's radiation damage algorithm so that it can be distributed to the radiation effects community. The code has passed preliminary testing.

- The MISSE6 materials have been tested, and the trays containing them have been sent to NASA for integration into a space shuttle payload.

- Detector measurements are ongoing. Currently, we are investigating the effect of various methods of surface passivation on the dark (noise) currents. New detectors have not been grown as the MBE system has been down.

- The ORMatE-1 devices (mirrors, mostly) have all been characterized and the hardware has passed its pre-flight thermal, vacuum and vibration tests. Presently analyzing data and writing various reports on the results of the pre-flight tests. It is scheduled to fly in 2008.

SIGNIFICANT FINDINGS AND CONCLUSIONS:

- So far the best passivation has been to minimize the exposed surface of the diodes by stopping the etch as soon as we are below the diode's depletion layer. Other passivations we have tried degrade the performance.

- ORMatE-1: optical profilometry of the samples showed considerable variation between the different technologies in terms of the number and depth of pits and scratches on the sample surfaces. Nevertheless, all the samples are good mirrors.

- We believe that the quantum efficiency(QE) of our detectors is limited by the electron diffusion constant of the superlattices which make up the detectors. We are currently evaluating new detector designs incorporating superlattices which have longer electron diffusion constants in the base of the diodes(detectors). We have measured the diffusion constants of the new superlattices, and are beginning to produce and test detectors incorporating the new superlattice designs.

- We have shown that our infrared detector diodes need to be more than 20 microns apart if the etch is stopped just below the depletion region. Otherwise, there is cross-talk between pixels. We are still investigating other passivation methods as diode arrays must be planarized.

ASSIGNMENTS: *(Electrical Engineer – Test Systems)*
- Misse-6 Testing: MZ simulator: Radiations measurements testing and various other measurements as assigned

CURRENT PROGRESS FOR EACH TASK:
- Misse-6 – testing and assembly
- MZ: maintain and improve performance, design and construct reference block as well as alternate boost sources

SIGNIFICANT FINDINGS AND CONCLUSIONS:
- Work is continuing. No significant findings to report.

ASSIGNMENTS: *(Researcher – Radiation Effects Measurements – Solar Cells)*
- Theoretical and experimental research on displacement damage radiation effects on semiconductor devices.
  - Radiation effects Modeling
  - Experimental radiation effects measurements
  - Data analysis
  - Writing papers/presentations/reports
  - Experiment set up/modification

CURRENT PROGRESS FOR EACH TASK:
- Simulation of charged and uncharged particle transport in materials. This involves using several advanced computer codes such as SRIM, MCNPX, GEANT4 and MULASSIS

- Calculation and use of no ionizing energy loss (NIEL) for particle correlation radiation damage studies.

- Space radiation environment calculations and modeling using such programs as SPENVIS and CREME96

- Solar cell degradation simulation in a space radiation environment using the NRL displacement damage dose and JPL equivalent fluence models

- Developing radiation environment specifications for various satellite missions

- Solar cell measurements

- Current-Voltage (IV) under various illumination source conditions

- Optical (quantum efficiency (QE), transmission/reflection)
- Radiation experiments performed at various facilities around the world NEOBEAM and NRL
- Dosimetric techniques (secondary dosimetric techniques in particle beam analyses using radiochromic films and other materials)
- Analyzing solar cell degradation data in the context of the JPL Equivalent Fluence and NRL Displacement Damage Dose models
- Analyzing radiochromic film data for use in accelerator dosimetry experiments
- Several papers/presentations were written/given (updated in resume)
- Making modifications to the solar cell IV lab at NRL. We are modifying our multisource solar simulator system to include transmission and reflection measurement capabilities with the use of a spectrophotometer. Also, LEDs are being investigated as possible sources for light bias
- Various programs that were used to run experiments are being converted to work under the Matlab program environment.
- In situ illuminated irradiation experiments are being planned for use at the NRL Pelletron radiation facility
- Optimizing how to run advanced particle transport codes such as MCNPX, geant4, and Mulassis
- Performing calculations, using several different codes (MCNPX, Mulassis, SRIM, MathCAD, and Shieldose) to simulate particle transport in materials such as borosilicate glass.
- Radioisotopic production calculations for various radioactive materials including 241am, 90sr and 210po.
- Solar cell pc-1d simulation and displacement damage calculations using Radioisotopic excitation.
- Space radiation environment calculations and modeling with such as spenvis and creme96
- Developing a code to simulate solar cell degradation in a space radiation environment using the NRL displacement damage dose model

- Understanding space weather in the attempt to update the current space radiation environment for earth orbiting systems

- Developing radiation environment specifications for the tacsat4 satellite

- Measuring radiation effects in thin film solar cells made of amorphous silicon (a-si) and copper indium gallium diselenide (cigs)

- Measuring optical properties of glass materials for radiation testing

- Several radiation experiments occurred at such facilities as Brookhaven National Laboratories, Naval Surface Warfare center, and NRL

- Measuring round robin radiation experiment o triple junction solar cells. This encompasses measuring solar cell properties both prior to and following proton and electron irradiated cells

- Performing QE measurements on boron carbide PN junction devices

- Analyzing several data sets on borosilicate glass particle irradiations

- Analyzing several data sets on thin film solar cell irradiations

- Analyzing solar cell degradation data in the context of the JPL equivalent fluence and NRL displacement damage dose models

- Several papers/presentations were written/given

- Making modifications to the QE and IV labs. We are modifying our multisource solar simulator system to include transmission and reflection measurements with use of a spectrophotometer. For the QE lab, the inclusions of different light bias techniques are being implemented. Specifically, the use of lasers and/or leds with existing light biases is being investigated. Also, the software is being updated to work under the MATLAB environment. Both of the measurement standards used in the QE system, a pyroelectric detector and a reflectance standard were recalibrated. In situ illuminated irradiation experiments are being planned for thin film solar cells.

3.3 TASK AREA 5

3.3.1 Subtask 1 – Microelectronic Design and Circuit Design, Testing and Fabrication
3.3.2 Subtask 2 – Wafer Bonding Fabrication and Characterization

ASSIGNMENTS: *(Research Scientist – Wafer Bonding)*

- Assist lab personnel with the growth of bulk gallium nitride crystals.

CURRENT PROGRESS FOR EACH TASK:

- GaN-based device operation is degraded by the lack of a low defect, high quality, lattice-matched substrate. Previously in the year, the growth of small platelets of high quality GaN by a novel low temperature, low pressure solution growth method had been demonstrated in this lab.

- In support of this endeavor, several investigations were run, including efforts to improve solvent preparation and determine the effects on both surface chemistry and growth morphology by experimenting with additives to the solution. The preparation of our solvent has been standardized and shows better quality. As for the effects of additives, one was found to completely clean the solution surface, while another shows great prospects in restricting crystal growth to only the c-direction. Crystals grown using this second additive show whisker morphology, on a □m scale.

- In addition, several improvements to the furnaces have been planned. It was determined that to improve control over crystal growth, a heat sink is necessary. This part has been designed and ordered. Another aspect to improve control is to rotate the solution during growth. A motor has been delivered and assembled to allow for this. It has been modeled and is waiting to be installed on the system.

ASSIGNMENTS: *(Electrical Engineer – Analog Circuit Design/Test)*

- Create preliminary set of alignment keys for detector masks and test other options.

CURRENT PROGRESS FOR EACH TASK:

- Finished preliminary set of alignment keys for detector masks

- Performed Shadow-mask metal & associated alignment key requirements.

- Constructed layer 9 shadow mask metal patterns & alignment keys

- Completed drawings of detector mask patterns

- Finished 400_round avalanche transistor & std bipolar transistor dwgs

- Completed layouts for 600_round &700_square size transistors, send by email

- Added 3u contact masks, use lOOu bond pad sizes on all chips

- Worked on layouts with 3u-wide contact masks, with metal 2u past contact openings

- Added Additional mask variations, PN & JBS Schottky diodes

- Worked on interdigitated bipolar transistors with 30 micron pitch

- Worked on IBS Schottky diode layouts
- Worked on layouts of IRS (Junction Barrier Schottky) diodes with 2 micron stripes
- Detailed DWGS of emitter and base stripes, add to transistor-diode note
- Masked layer his; SIC transistor tests;, partial-discharge testing
- Fielded plate (Fl') tapered dielectrics, floating ring vs PP
- Tapered-Resist mask test results; concave & convex tapers
- Finish revisions to bipolar transistor mask layouts
- Finish revisions to IBS diode mask layouts
- Finish drawings for pogopin jig for JBS diode, 2 versions tests
- Tested thermal cycling using quartz heater & forced-air cooling
- Finish drawings for self-aligned SIC WETs
- Begin work on new JFET design with 6u stripes of polycrystalline silicon
- Located 10 ampere MOSFET test fixture with 5 source pins
- Finished drawings for WET design with 6u stripes
- Finished tests of quartz-heater thermal cycling equipment
- Finish new SiC JFET masks
- Finished drawings for strip detector containing 32 strips
- Revise 32-strip detector from 15 lines P+, 14 lines N+ to 16 lines P+, 15 lines N+
- Work on 32-strip detector & several variations of detector pixels
- Finish drawings and note for detector structures
- Begin work on design of imaging-array detector
- Finish noting describing preliminary design of imaging-array detectors

- Work on several different variations for detector array

ASSIGNMENTS: *(Processing Technician)*

- Perform integrated circuit processing procedures including optical lithography, plasma etching, high temperature processing and substrate cleaning. Maintain lab and equipment for these purposes.

CURRENT PROGRESS FOR EACH TASK:

- Performed optical lithography and metal etching on GaN samples. Optical lithography and reactive ion etching of diamond films. Develop lift-off lithography using bi-level LOR/photoresist scheme. Barrel etch poly silicon samples. Set up a high temperature furnace for Silicon carbide oxidation. Install new water storage tank for the water purification system. Repair DUV mask exposure tool.

ASSIGNMENTS: *-Electrical Engineer*

CURRENT PROGRESS FOR EACH TASK:

- New thermally stimulated current (TSC) spectra were obtained using liquid helium for device cooling. These spectra were different from the previous results, and from the literature, but the physics makes sense and further analysis is under way.

- In addition, a poster entitled "Investigation of NCD as an Ohmic Contact to GaN" was prepared and presented at the ISDRS conference in College Park, MD, during December 12-14, 2007.

- C-V measurements were performed on SiC oxide capacitors and ALD oxide capacitors, both with good results.

- Work was done mainly on the setup for measuring thermally stimulated current (TSC) on 4H-SiC devices. Initial TSC spectra were obtained on several wirebonded capacitors that agreed with the published literature. IV, CV, quasi static CV measurements were performed, as well as Dit analysis.

- Ohmic contacts were patterned on six GaN/SiC samples. The contacts were annealed and 300nm PECVD oxide was deposited on top. The oxide was patterned with a mesa mask and was RIE etched. The resist was removed in PR stripper and the samples were ashed.

- GaN ICP is to be performed in the beginning of November.

- A shipment of about $70,000 worth of semiconductor characterization equipment purchased on surplus for $5300 was delivered and set up in the lab.

- TLM measurements were performed on six NCD/GaN samples to determine the NCD sheet resistance. In addition, sheet resistance was measured with a Lehighton instrument.

- The 8 wafers with GaN devices were sawn and are ready for annealing. Additional training at NSI was performed on thermal evaporation. Samples were wirebonded for the TSC measurement setup.

- The VASP simulation package was comp

ASSIGNMENTS *(Researcher/Radiation Image)*

- Large format imaging arrays for satellites
- Secure Satellite Communications
- High performance reconfigurable computing
- Risk mitigation in emerging technologies for satellites
- Anomaly resolution in satellite systems

CURRENT PROGRESS FOR EACH TASK

- Assigned to support development activities for an OGA to participate in research and development of new technologies for very large format area imaging arrays to cover both the visible (~100 megapixel) and infrared (~4 megapixel) bands. Requires participation in requirement definitions for development contracts, participate in periodic technical interchange meetings and contract reviews, and help plan and conduct radiation testing to assess potential vulnerabilities in candidate application scenarios. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of semiconductor groups and circuit implementations.

- Work closely with OGA procurement personnel in the retrofitting of Communications Security (COMSEC) avionics hardware for high speed secure communications in the multi Gbit/s regime. Because of involved in the development of this hardware, engagement has taken place to assist in the replacement of key high speed gallium arsenide GaAs components (which are no longer available) with a replacement "drop in" e solution using Silicon Germanium (SiGe) circuit technology. One primary responsibility is to assure this replacement circuitry for the KG247 COMSEC unit will perform satisfactorily in the harsh space radiation environment, and in particular meet stringent requirements for immunity to "loss of sync" conditions which would require ground station intervention to recover. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of semiconductor groups and circuit implementations.

- In a separate task, worked with the same OGA and its satellite user community to establish the performance and radiation requirements for the Next Generation Encryptor (NGE) development. This participation is through the High Speed Encryptor Task (HSET) and involves interactions the OGA and its two contractor teams presently involved in a study contact phase leading to a limited procurement next year. The primary capacity is to advise the OGA procurement specialists in the hazards of using high performance technologies for NGE applications in the presence of harsh radiation environments and interact with the contractor teams so that their design concepts are reasonable with these hazards in mind. This work involves participation in many different government development efforts aimed at developing radiation tolerant and radiation hardened technologies to stay abreast of the potential for the insertion of new technologies and new design architectures in future COMSEC systems which will be required to operate in harsh environments with data throughputs approaching 100 Gbit/s. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of semiconductor groups and circuit implementations.

- Includes support for NRL and the OGA in a development activity to produce hardware suitable for high performance Polymorphic Computing Architectures (PCA) for implementation in multicore processors operating on a single microcircuit and using 49 radiation hardened parallel processors per node to achieve computing tasks at ~70 giga operations per second (GOPS). The aim of this task is to provide the OGA satellite community with resource-efficient high performance computing for on-board satellite payload processors, and do so with accommodation for ground station uploads for reconfiguration as well as autonomous agile algorithm situations. The approach taken to achieve this involves the DARPA/DTRA co-funded Rad Hard By Design (RHBD) program's cell library, and is done in close conjunction with the Boeing microelectronics design center at the Kent, WA Phantomworks location. The key responsibilities are to collect and disseminate vital knowledge of the role of charged particle induced single event upsets and single event transients and to inform the OGA of associated risks. Also, includes participation as part of the design team to assess potential circuit modifications and fault tolerant hardware and software solutions to assure reliable computing for this task. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of circuit implementations.

- In a closely related task, over much of the past year has been spend serving as the Principle Investigator (PI) for the demonstration of PCA on the MISSE-7 space experiment on board the International Space Station (ISSA). This experiment will

integrate a commercial multicore processor board from Tilera, Inc. for demonstration on orbit, and later the card will be retrieved by Space Shuttle astronauts for post flight analysis.

- This task includes support of NRL and an OGA System Program Office (SPO) to assess performance of new technologies of interest in both satellite bus and in satellite payload performance enhancements. Over the past year, this task has included work on new signal processing approaches and the hardware associated with enabling it, attitude determination with radiation hardened star trackers, on-board high speed optical communications via fiber optical transceivers, and radiation environment monitoring using on-board sensors. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of circuit implementations.

- In a task closely related to item 4, involvement has taken place in investigations of spacecraft anomalies, and in particular with attention to the role of radiation effects as it induces single event phenomena and also in the permanent degradation of microelectronic device performance. This activity involves interactions on an as-needed basis with the satellite prime contractor, its subcontractor team members, and the government SPO. This work involves collaborative interactions with OGA procurement teams, other national labs, and contractor teams, and requires a working knowledge of satellite operational scenarios, space radiation environments, and interactions of charged particles and ionizing photons in a variety of circuit implementations.

4.0 SUMMARY

Work for the upcoming year will include:

- SFA will continue to investigate different detector designs and surface passivations and operation in the 5 micron wavelength regime.

- The new detector designs will be tested.

- The MATLAB code will be evaluated to determine what features should be added and further testing will be performed.

- ORMatE-1: Results of the ORMatE-1characterization will be reported at the National Space and Missile Materials symposium. Some modifications to the package which holds the experiment will be made as it is slightly over the weight specifications.

- Mz: maintain and improve operating procedure, investigate methods of modification

- Misse-6 Delivery and Further Testing
- Misse-7 Planning and Testing
- Gaas experiments
- Various measurements
- MBE machine operation
- Implementation of the NRL displacement damage dose model into the web-based format spenvis.
- Radioisotope excitation and damage production on solar cell modeling and experiments
- Satellite radiation effets qualification analyses
- The mechanical tools will soon be available to allow better control over crystal growth, while experimental knowledge has also increased to develop a better process. It should be an exciting year in bulk growth. Bulk growth research should progress forward.

Appendix A
Abbreviations and Acronyms

AL.................... Aluminum
ALN.................. Aluminum Nitride
A-Si.................. Silicon
AU.................... Gold
CIGS................. Copper Indium Gallium Diselenide
CR.................... Crome
DHBT................ Double Heterojuction Bipolar Transistor
DUV.................. Ultra Violet
FP..................... Field Plate
GaN................... Galium Nitride
GDS................... Generated Drawing Specification
GEANT4............. Name of mission
HEMT................ High Electron Mobility Transistor
Ids..................... Indentify
IGBT................. Insulated Gate Bipolar Transistor
ITS.................... Software code
JBS.................... Junction Barrier Schottky
JFETs................. Junction Field Effect Transistor
JPL.................... Jet Pulposuim Laboratory
JTE.................... Junction Termination Extension
MBE.................. Molecular-beam epitaxy
MCNPX.............. Software code
Misse6................ Satellite expected to carry ORMatE-1
Misse7................ Satellite expected to carry ORMatE-2
MOSFETs............ Metal Oxide Semiconductor Field Effect Transistor
MQW.................. Quantum Well Nanomachining
MULASSIS.......... Mission title
MZ..................... Multi-Zone
NASA................. National Aeronautics and Space Administration
NRL................... Naval Research Laboratory
ORMatE-1........... Optical Reflector Materials Experiment - 1
PN..................... Positive/Negative
QE..................... Quantum Efficiency
SiC.................... Silicon Carbide
SRIM.................. Software code
STD................... Standard